NSW Resources Regulator

Preventing Fires on Mobile Plant

Discussion paper August 2018

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Foreword

Purpose

This discussion paper provides an overview of fires on mobile plant in New South Wales mines and considers strategies to reduce the incidence of fires.

It is a first step in consultation regarding the use and possible regulation of mitigation strategies, such as surface temperature control and the use of fire-resistant fluids in mobile plant in NSW mines. The Resources Regulator seeks feedback on the current and future use of fire-resistant fluid in mobile plant in New South Wales mines and other solutions, for example temperature control by water jacketing and other methods, to reduce the number of fires on mobile plant.

The paper is intended to inform the development of policy, guidelines and regulatory improvements and as such should not be taken to be current New South Wales Government policy.

Contents

Introduction

A review of data has identified a concerning increase of reports of fires on mobile plant in New South Wales. The Resources Regulator recognises the need to prevent fires in mines and to minimise the severity of a fire event, should it occur.

Fires are generally caused by either the escape of fluids ignited by the hot surface of an engine, or electrical wiring faults.

Mine operators have a duty of care to provide and maintain a safe working environment. Adequate fire protection is a regulatory obligation and is also financially and operationally critical.

Fires on mobile plant

Fires on mobile plant are dangerous for the operator when they inhale the products of the fire, mainly carbon monoxide and toxic emissions; inhale hot air/gases; are burned by flames; or fall while exiting large mining vehicles.

Fires on mobile plant in underground mines can be particularly dangerous due to the enclosed spaces involved, potentially large amounts of smoke and toxic gases and difficulty in evacuating quickly, possibly resulting in entrapment, smoke inhalation, asphyxiation and serious or fatal burns. Risks to workers from fires underground are higher than risks of fire on surface vehicles as more people are potentially exposed to the products of fire, particularly if tyres are involved. A fire in an underground coal mine has the potential to escalate to a catastrophic event due to the ignition of an explosive atmosphere.

There are several inherent fire risks on mobile plant including:

- mobile plant fuel, coolant or oil escape onto a hot surface such as exhaust manifolds or turbochargers
- engine or turbo failure
- electrical wiring hot joints
- high current or circuit overloading (starting, regeneration etc)
- interaction with high voltage power cables
- tyre pyrolysis
- sound and heat insulation and lagging material deterioration or material being soaked with oils, fuels or degreaser products (self-oxidative heating)
- mechanical hot joint, such as bearing failure or brake overheating.

Potential ignition sources on mobile plant include:

- heat: hot surfaces on engines, exhaust systems, and turbo chargers
- electrical: electrical discharge in motors, retarders and transformers, short circuit arcs, earthing faults, static electricity discharge and mobile equipment contact with high-voltage power cables
- mechanical: cutting, friction, mechanical impacts, grinding
- chemical: self-heating, auto-ignition, exothermic reactions, pyrolysis of tyres.

High fluid pressures in hydraulic systems mean that any lack of integrity in the system can result in a hose burst or even a small leak. Failure of piping, joins and fittings, valves and gaskets and rupture of flexible hoses are the main cause of fluids being released from a system. This can result in a serious fire when hydraulic fluids are ejected under pressure from hydraulic systems in the form of jet, spray or fog and the fuel contacts a hot turbo or exhaust manifold.

In addition, hydraulic fluid spilled during transport or leaking from hydraulic systems onto absorbent materials, such as lagging or dust, can ignite and cause a fire along the fluid-wet absorbent material.

Fires on mobile plant in New South Wales

Mine operators are required to report dangerous incidents, including fire, under section 14(c) of the *Work Health and Safety (Mines and Petroleum Sites) Act 2013*.

Between September 2014 and May 2017, 203 fire events were reported, an average of 6.2 fire events per month. Previous data collected between 2001-2008 shows an average of 3.1 fires reported per month.

In September 2017, the Resources Regulator published the findings of a review of data on fire incidents (In-service fires on mobile plant) drawn from dangerous incident notifications. In the 12 month period reported on as part of the review, between May 2016 and May 2017, 97 fire events were reported, an average of eight fires per month.

Between 1 January 2017 and 31 December 2017, 114 fires on mobile plant in mines were reported, an average of 9.5 fire events per month. Reporting up to May 2018 shows an average rate of 8.4 fires per month, extrapolating to 103 fires anticipated for 2018 if fire incidents continue at the current rate. The Resources Regulator now publishes a quarterly report of fires on mobile plant.

Further detailed analysis of the 2017 incident reports has revealed that mobile equipment at open cut coal mines account for most of the fire incidents reported to the regulator. The majority (70 per cent) of fires on mobile plant occurred on surface coal mines, 19 per cent happened in underground (non-coal) mines and 10 percent of fires occurred at non-coal surface mines. Less than one per cent of fires (a single fire) happened in an underground coal mine.

Of the 114 fires reported in 2017, 80 (70 per cent) were due to the release of a fluid, of which 37 fires (32 per cent) were attributed to the release of hydraulic fluid. The heat source in all but one hydraulic fluid release was the hot exhaust components of the engine. There is a clear indication that hot surface and inadvertent release of combustible fluid are the dominant causal factors of fires on mobile plant.

The following table shows the type of mine and number of incidents caused by escape of fluid.

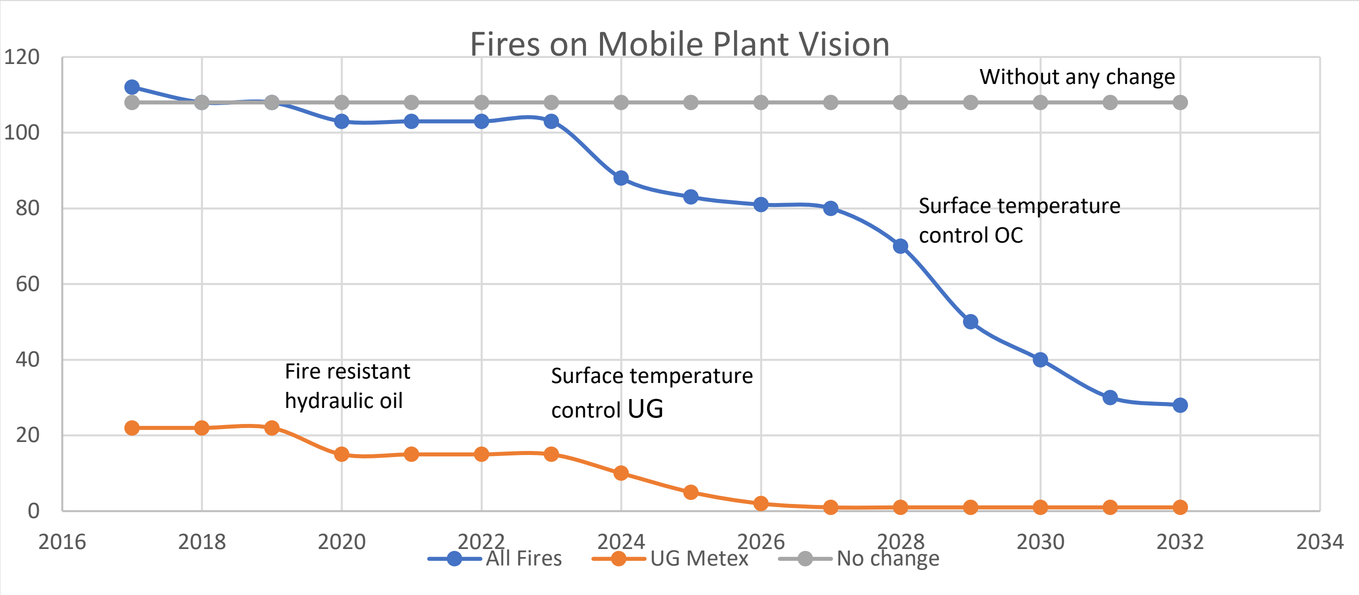
Mine Type	Number of fire incidents 2017	Fires caused by escape of fluid	Fires caused by escape of fluid – hydraulic fluid
Underground coal	1	0	0
Surface coal	80	61	30
Underground (not coal)	22	12	4
Surface (not coal)	11	7	3
TOTAL	114	80	37
Percentage	100%	70.18%	32.46%

Reduction of surface temperatures on mobile plant

Strategies to reduce fires on mobile plant ultimately need to address the control of surface temperature to eliminate the risks associated with fluids making contact with hot surfaces.

Currently in underground coal mines in NSW, surface temperature for diesel mobile plant is controlled to be less than 150° Celsius. Original equipment manufacturers do not generally incorporate surface temperature controls into the design of mine vehicles used in the underground metalliferous mines and surface mines. Surface temperature controlled diesel engines are commercially available for industries where fire must be controlled, such as marine and petroleum applications. Many of the engines currently used in mining vehicles are available in wet (water jacketed) exhaust configuration that typically controls engine surface temperature adjacent to water jacketed areas to 200°-250° Celsius.

The following table illustrates a vision that a reduction of fires could occur with the immediate introduction of application of fire-resistant hydraulic oil in underground metalliferous mines. The introduction of surface temperature control in both underground metalliferous mines and open cut mines will impact on 69 per cent of fire events overall. Without any change to existing controls the industry cannot expect any reduction in fires in NSW mines.



Temperature control in underground coal mines

In the design of diesel mobile plant for underground coal mines, surface temperature is controlled to be less than 150° Celsius for all modes of operation. Exhaust manifold, turbo, exhaust pipes and compressors are cooled by water jackets. Explosion protection techniques including Ex d and Ex i are used for electrical systems providing heavy duty protection of cables and connections. Start systems are pneumatic, eliminating the risk of batteries, starter motors and high current draw. In addition, brakes are oil immersed and totally enclosed.

These robust safety features of underground coal vehicles are fundamentally integrated by mechanical and electrical design, eliminating the presence of hot surfaces and sparks. Resources Regulator statistics show that these characteristics have proven to be highly effective in preventing fires on mobile plant in underground coal mines, with only one reported fire on mobile plant in a NSW underground coal mine in 2017, caused by tyre pyrolysis.

In underground coal applications, maintaining a surface temperature control of less than 150° Celsius targets the minimum ignition temperature of some specific coal types.

Surface temperature controls in underground metalliferous and surface mines

Engine exhaust surface temperatures continue to contribute to fires on mobile plant, accounting for 69 per cent of heat sources in reported fires in 2017.

Surface temperature controls are not implemented by original equipment manufacturers for metalliferous and surface mines to the same degree as for underground coal mines. Lagging and double skin options are used to insulate hot surfaces however lagging can absorb leaking fluids such as oils, coolant and diesel and has been shown to cause or feed fires on mobile plant. Attempts to contain fluid are effective most of the time, however, when fluid containment fails and the fluid contacts the hot exhaust system surface, a fire will usually occur.

While the surface temperature control to 150° Celsius targets ignition temperatures specific to underground coal mines, reduction of surface temperature to less than 150° Celsius may not be necessary to eliminate fires in underground metalliferous and surface mining applications. The vehicles involved in fire events reported to the Resources Regulator have typically involved dry exhaust systems that operate up to or above 500° Celsius.

The minimum hot surface ignition temperature depends on a number of factors including the physical properties of the liquid, the concentration of fuel in the air, the droplet size and the shape and size of the heated surface. A literature review undertaken by the Health and Safety Executive (UK) concluded that the measured minimum hot surface ignition temperature of unconfined sprays is typically more than 60° Celsius above the auto ignition temperature. Given the auto ignition temperature of diesel fuel is 204° Celsius, a surface temperature target of 250° Celsius would support a reduction in the occurrence of fires on mobile plant. Further safety would be obtained if the surface temperature of mobile plant is controlled to 200° Celsius to align with the auto ignition temperature of diesel fuel.

It should be noted that fluid soaked into porous insulating material, such as lagging, can ignite at temperatures below the auto ignition temperature by oxidative self-heating, therefore surface temperature control may not be completely effective in these situations and the use of fire-resistant fluids may mitigate the risks of fires in situations where insulating material is used on mobile plant.

The table below illustrates the temperatures associated with a variety of mining applications and ignition points:

Hot surface	Temperature
Touch	50° Celsius
Burn	80° Celsius
Underground coal limit	150° Celsius
Ignition of coal dust layer	160° Celsius
Turbo compressor volute	180° Celsius
Wet engine turbo and exhaust	200-250° Celsius
Ignition of diesel fuel	330-370° Celsius
Ignition of hydraulic oil	390-440° Celsius
Turbo dry exhaust	400-550+° Celsius

Use of mineral oil in mobile plant

The most commonly used liquid for hydraulic power systems, such as those in mobile plant on mines, is mineral oil. Mineral oil is used because of its excellent lubricity, it is available in several viscosities and is relatively low cost.

Hydraulic oil may be considered high risk because, while mineral oil is not readily ignited in bulk, it is highly flammable when sprayed onto a hot surface. Mineral oil hydraulic fluid, when released under pressure, such as in the case of hose failure, produces a stream or vapour which can be ignited on a hot surface, such as mobile plant exhaust. This type of fire can release toxic gases and significant heat in a fireball.

Guidance on the use of fire-resistant fuels, published by the International Standards Organization (ISO), states that "In circumstances where ignition is likely, such as in a steel mill, or where released fluid cannot be allowed to propagate a fire, as in a coal mine, an alternative, fire-resistant, fluid must be used". (*ISO7745:2010 Hydraulic fluid power— Fire-resistant (FR) fluids — Requirements and guidelines for use*).

Types of fluids on mobile machinery

Mobile machinery in mining use different types of fluids which may be pressurised and give rise to a fire hazard. These include:

- Hydraulic systems
- Braking systems
- Fluid transmission, torque convertors, transmission retarders
- Engine and turbo lubricating oil
- Greases
- Radiator coolant

There is not always a fire-resistant version of fluids for every system used in mining. For example, there are no known or practical alternatives to engine lubricating oil, diesel fuel or greases. There are fire-resistant alternatives to coolant and hydraulic oils on the market.

Substituting a fire-resistant fluid

Fire-resistance and physical properties, such as viscosity and lubricity, vary widely among the several types of fluid available. Special precautions need to be taken when changing fluids on machinery.

Several factors need to be considered before switching to a fire-resistant fuel. It is crucial that these factors be addressed to mitigate against unintended consequences. Factors that need to be considered include:

- operating temperature
- viscosity
- compatibility
- chemical and thermal stability
- air release and foaming
- shear stability
- filterability
- density
- vapour pressure

Incompatible substitutions could influence safety critical systems such as steering and brakes. An engineering analysis should be undertaken when fluid is being substituted and special care should be taken when changing from one fire-resistant fluid to another as they are not all compatible. It is crucial that fire-resistant fluids are matched to the proposed application and the perceived hazards of use.

Water is readily available and non-flammable but it has low viscosity and poor lubrication, temperature limitations and gives rise to erosion, corrosion and cavitation. Water is also affected by temperature and might not be suitable for hydraulic systems that operate at high temperature. However, technology is available that allows the use of water or water with corrosion inhibitors as hydraulic fluid. Where fire-resistance is a requirement, hydraulic applications usually use specially formulated fluids which perform better than water.

The disadvantages of fire-resistant fluids may be overcome by additive technology or system design. Machinery may need to be designed or altered to use fire-resistant fluids.

Using a fire-resistant fluid in older plant that is designed for mineral oil may cause seal degradation and excessive wear. Synthetic fluids cannot always be used with common nitrile elastomers because swelling and shrinkage of seals can occur. Temperature is a significant consideration as fluid viscosity will change due to variations in temperature.

ISO 7745:2010 *Hydraulic fluid power— Fire-resistant (FR) fluids — Requirements and guidelines for use* provides the guidelines and requirements for fire-resistant hydraulic fluids. ISO 12922 *Petroleum and related products -- Determination of spray ignition characteristics of fire-resistant fluids* provides the specifications for hydraulic fluids including HFDU.

HFDU Fluids

HFDUs are synthetic, anhydrous, fire-resistant hydraulic fluids, designed to replace mineral-oil-based hydraulic fluid where fire hazards exist. They are the most compatible fire-resistant fluids for use in mineral oil applications, especially for later model machinery with modern components and can be used as a direct substitute. HFDUs are miscible with mineral oil hydraulic fluid and compatible with elastomers designed for use with mineral oil. A high-performance lubricant, HFDU can operate at high temperatures and pressures, has excellent shear stability and oxidation stability, optimal performance characteristics, high lubricity and anti-wear properties. HFDU is claimed to be biodegradable and environmentally sensitive.

It should be noted that while HFDU is the most compatible with mineral oil, it is the least fire-resistant. It cannot pass the wick test, however, it is considered less flammable than mineral oil.

Because major plant manufacturers sell to an international market, many of which have fire-resistance requirements, manufacturers will have plant options that are compatible with fire-resistant fuel. Manufacturers will also recommend HFDU fluids that are compatible with mineral oil hydraulic fluid plant. Current manufacturers of hydraulic equipment use seal materials that are fully compatible with ester based hydraulic fluids, however, the use of HFDUs should be assessed in each case.

HFDU is estimated to be between three to five times more expensive than mineral oil, however, the cost may decrease as use increases.

Because it has better wear characteristics, HFDUs require less frequent hydraulic oil changes and savings may be made on reduced wear, as well as avoiding partial or total destruction of mobile plant in the case of a fire.

HFE Fluids

Because of the of high risk associated with a longwall fire, longwall roof supports use HFE water emulsion fire-resistant fluid, however, valves and components have been specially designed to tolerate low lubricity, low viscosity and low operating temperature. HFE fluids are the most fire-resistant but cannot be used on machinery designed for mineral oil.

HFDR Fluids

HFDR fluids may be closely compatible, but pressure and temperature ratings may be insufficient. HFDRs are used in tunnel boring machines where fire-resistant fuels are mandated.

Mechanical and Electrical Design Factors

Mechanical design changes and best practice design also mitigate the risks of fires on mobile plant. Ensuring that hydraulic lubrication and fuel lines are routed, fastened, clamped and segregated away from hot surfaces, and joints, fasteners, supporting brackets and fittings are well engineered, will lessen the incidents of fires.

Best practice circuit design and wiring installation can minimise electrical hot connections. Increased protection of electrical wiring will support a reduction of fires on mobile plant.

Improvements to maintenance practices, making sure appropriate maintenance regimes are adhered to and checking that vehicles are in a fit for purpose condition to enter a mine, will also support the reduction of fires on mobile plant.

Discussion

In the hierarchy of risk control, wherever practical, the hazard, such as potential fuel and ignition sources, should first be eliminated. If elimination is not possible, the fuel and/or ignition source should be substituted to a less hazardous one.

All mobile equipment fuel, lubrication and hydraulic system fluids are potential fuel sources for fires. As these fluids cannot be eliminated, it is generally recommended that fire-resistant materials are used wherever practical, however, there is not a fire-resistant fluid available for every application.

The use of a fire-resistant fluid, to replace mineral oil in hydraulic systems, has the potential to reduce the incidence of, but not eliminate, fires on mobile plant. Based on 2017 figures, if all mobile plant hydraulic systems in New South Wales mines replaced mineral oil with HFDU, with 100 per cent effectiveness of eliminating fires, a potential 32 per cent reduction in reported fires on mobile may result.

However, it should be noted that a 100 per cent success rate is unlikely because while HFDU is less flammable than mineral oil, it is unable to pass the wick test of fire-resistant fluids. It is also noted that the underground coal sector only had one reported fire on mobile plant in 2017, therefore there may be limited utility in adopting HFDU across this sector.

The hot surface temperatures of diesel exhaust system components and hot electrical joints are the dominant ignition/heat sources of fires on mobile plant. Reduction of surface temperatures, for example by water jacketing exhaust, may be used to eliminate or reduce the ignition/heat source if a combustible fluid escapes. The effectiveness of prescribed controls around low surface temperatures is self-evident when it is considered there was only one fire reported on an item of mobile plant in an underground coal mine in 2017.

With the apparent effectiveness of these engineered solutions used in underground coal mines it beneficial to examine whether these controls be adopted by other types of mines. In particular, it is noteworthy that other underground mines (i.e. non-coal) accounted for 19 per cent of the reported fires in 2017. Underground mines present additional risks which were demonstrated in a recent incident detailed in Safety Alert SA18-08.

While the consequences of fires (in terms of catastrophic risk) on the surface may be considered lower than in underground mines, surface coal mines accounted for 70 per cent of fires in 2017, with 30 fires (or 26% of the total) attributed to escapes of hydraulic fluid. Notwithstanding the perception of lower risk, every time a fire ignites on large mining plant, the operator is exposed to the risk of rapid engulfment, the hazards of the products of combustion, the potential for loss of control of the machine, and the risk of serious injury while attempting to dismount the machine to escape the fire.

Surface mines (other than coal) reported 11 fires (around 10 per cent of the total number of fires reported), with three fires attributed to the escape of hydraulic fluid.

Other strategies to mitigate against fires on mobile plant include increasing the protection level of electrical wiring, ensuring segregation of hydraulic lines from electrical cables and hot surfaces, covering hydraulic lines to prevent pressurised leaks or bursts onto hot surfaces and ensuring hydraulic hose temperature is compatible with the operating temperature. This would reduce the escape of hydraulic fluid and therefore reduce the number of hydraulic fluid related fires. In addition, undertaking routine and regular maintenance of mobile plant would enable mine operators to identify faulty fittings and hose issues before they cause problems.

While newly designed and manufactured plant could be supplied to use HFDU and/or other fire-resistant fluids, they may still be affected by fire unless surface temperature, segregation issues, electrical wiring and maintenance are considered alongside fire-resistant fluids.

Another related factor is increased cost to purchase fluids and maintain equipment, as well as a possible increase in the downtime of equipment for maintenance. If diligent maintenance practices are adhered to, there may be no reduction of component life involved in using fire-resistant fluids.

Surface temperature controlled diesel engines are commercially available for marine and petroleum applications and many engines used in mining plant are available in wet (water jacketed) exhaust configurations that control engine surface temperature to 200-250° Celsius.

It is also of note that an ISO Standard for underground mobile plant is currently under development (ISO/FDIS 19296: *Mining – Mobile machines working underground – machine safety)*. An ISO Standard for Earth Moving Machinery is also currently under development (ISO 13649: *Mining – Earth Moving Machinery – Fire Prevention)*. Consideration will be given to its adoption once it is finalised.

In summary, when considering the application of the hierarchy of controls to manage the risks of fires on mobile plant, it is arguable that technology, in terms of equipment design and lubrication options, is available that would serve to virtually eliminate fires on mobile plant.

The Resources Regulator will continue to analyse fire event data and work with mine operators to understand the reasons for the increase of fire incident reports.

The consequences of an uncontrolled fire in an underground coal mine are potentially catastrophic.

Have your say

The Resources Regulator is seeking written submissions on the subject of this discussion paper. You can make an individual submission or contribute to a joint submission through your employer, union, professional association, work health and safety group or committee or other forum. You are invited to respond to some or all the questions posed in this discussion paper and provide any additional information on matters you think should be considered in relation to the use of fire-resistant fluids in mobile plant in mining applications.

Please provide your submissions to rr.feedback@planning.nsw.gov.au by 14 September 2018. This discussion paper and details about how to make a submission are available at: https://resourcesandgeoscience.nsw.gov.au/regulation/stay-up-to-date/have-your-say.

Submissions on this discussion paper will be considered by the NSW Government when investigating the potential for regulating the use of fire-resistant fluids or other fire mitigation strategies. Submissions or summaries may be published on the Resources Regulator website. If you do not want your submission to be published please advise us that you do not want your submission to be published or that you wish to keep parts of your submission private, such as your name and contact details.

Questions

From mine operators, the Resources Regulator seeks to understand the current use of HFDU and other fire-resistant fluids in mobile plant.

- Are you currently using HFDU in mining plant?
- Are you currently using fire-resistant coolant?
- Are you using any other fire-resistant fluids?
- Why did you make the change or why haven't you made the change to fire-resistant fluids?
- What are the barriers to introducing fire-resistant fluids for mobile plant on mines?
- If you have switched to HFDU, in some or all mobile plant, what was your experience in switching from mineral oil to HFDU or other substitutions that have been made.
    - Were there any issues with components, brakes, changes to the operations or safety of the plant?
    - Was cost a factor
        - Are there additional costs associated with changeover and ongoing maintenance?
        - What is the cost of HFDU in comparison to mineral oil?
    - Has the use of HFDU in mobile plants resulted in increased or decreased reliability of the plant?
    - Were there any unintended consequences or new risks related to the introduction of fire-resistant fuels?
- What other fire reduction strategies do you have in place or are you considering implementing such as:
    - water jacketing
    - other surface temperature control methods
    - segregation improvements
    - maintenance improvements

From Original Equipment Manufacturers, the Resources Regulator seeks to understand the specifications for the equipment in relation to the use of HFDUs and other fire-resistant fuels.

- What HFDU/fire-resistant fuel ready plant is currently available for the Australian mining market
- How compatible is HFDU with currently operating mobile plant?
- Can HFDU be directly substituted for mineral oil in currently operating mobile plant?
- Is there currently any intention to implement surface temperature control design methods for mobile plant used on underground metalliferous mines and surface mines?
    - What would be the cost difference of surface temperature controlled vehicles compared with those currently used?
    - Is it feasible to retrofit existing vehicles with surface control measures such as water jacketing and what would be the additional cost?
- What consideration is given to the potential of fires on mobile plant in the design and engineering of mobile plant?
    - Could more be done in the design of mobile plant to eliminate the risk of fires?

From manufacturers of fire-resistant fluids, the Resources Regulator seeks to understand:

- What are the requirements for safely handling fire-resistant fluids?
- Are there potential health issues arising from handling fire-resistant fluids?
- What is the cost of HFDU in comparison to mineral oil?
- How is HFDU disposed of?
- What are the environmental considerations for using HFDU?

Appendix A – Fire-Resistant Fluids

Development of fire-resistant hydraulic fluids

The development of fire-resistant hydraulic oils can be traced to three major events: World War II, the disaster at the Bois de Cazier mine and the 1973 oil crisis. In particular, the Bois de Cazier mine accident, near Marcinelle in Belgium in 1956, in which 267 miners died, led to the Luxembourg Report, which established the specification for hydraulic fluid in the mining and extractive industry in Europe. Following this, other countries developed or adopted regulations on fire-resistant hydraulic fluids.

What is a fire-resistant fluid?

Fire-resistant hydraulic fluids are lubricants that are difficult to ignite and do not tend to propagate a flame from an ignition source. Fire-resistant is not the same as fire-proof — fire-resistant fluids will still ignite and burn in the right conditions. Only 95 per cent water based emulsions can be considered fire retardant. Fire-resistant fluids are generally used in applications where a hydraulic fluid might come into contact with a source of ignition or hot surface.

Fire-resistant fluids obtain their fire-resistance from either the presence of water (aqueous fluids) including oil and water emulsions and water polymer solutions or the chemical composition (anhydrous fluids) that are free of water, including anhydrous synthetics. Fluids that are water based have a much higher fire-resistance, however, there is a trade-off between lubricity and fire-resistance.

The ISO classifies fire-resistant fluids as follows:

- HFAE: oil-in-water emulsions, typically with more than 80% water content
- HFAS: synthetic aqueous fluids, typically with more than 80% water content
- HFB: water-in-oil emulsions, typically with more than 40% water content
- HFC: water polymer solutions, typically with more than 35% water content (also known as glycol solutions, polyalkylene glycol solutions or water glycols)
- HFDR: synthetic anhydrous fluids composed of phosphate esters
- HFDU: synthetic anhydrous fluids other than phosphate esters, such as polyol esters and polyalkalene glycols

Tests for fire-resistant fluids

There are several different tests to assess fluid fire resistance. Refer to the following:

- Flash point test (open cup or closed cup) to determine the flash and fire points of petroleum products to determine suitability of fluid to form flammable mixture with air and then support combustion. (AS 2106.2; ISO 2719)
- Spray ignition test to assess persistence of a flame with pressurised spray of fire-resistant fluid. (ISO 15029.1 & 15029.2)
- Wick test to assess the persistence of a flame applied to the edge of a wick of non-flammable material immersed in fire resistant fluid to assess the bulk behaviour of fluid, relevant to safe transportation and storage. (ISO 14935)

- Manifold ignition test to check relative flammability of fluids when contacted with hot metal surface at fixed temperature and to gauge ignition temperature through manifold temperature adjustment. Used to test resistance to ignition of fire resistant fluids. (ISO 20823)

Appendix B – Legislation, guidelines and standards

Legislation

Work Health and Safety Act 2011, contains provisions relating to duty of care and safe systems of work and ensuring the health and safety of workers and others who may be affected by a work activity, and provisions for the management of risks.

Work Health and Safety Regulation 2017 includes provisions for specific control of fires and explosions, fire protection and firefighting equipment and provisions on PPE and emergency plans

Work Health and Safety (Mines and Petroleum Sites) Act 2013 includes provisions regarding notification of dangerous incidents.

Work Health and Safety (Mines and Petroleum Sites) Regulation 2014 includes provisions specific to principal hazard management and control measures for fires or explosions, and provisions on emergency response Further legislation

Coroners Act 2009 empowers coroners to investigate fires and explosions that destroy or damage property or those where people have been injured within the state. This allows coroners to determine the causes and origins of, and in some cases, the circumstances concerning fires and explosions.

Fire Brigades Act 1989 and *Rural Fires Act 1997* outline the powers of fire authorities to access property to suppress fires and conduct investigations, along with specific requirements about the notification of fires during bush fire danger periods.

Guidelines

The Resources Regulator publishes mining design guidelines (MDG) in risk management approaches to fire hazards and recommends minimum standards.

MDG15 *Mobile and transportable plant for use on mines and petroleum sites* deals with mobile plant operating on all mines other than underground coal mines.

MDG 3602 Material testing for hydraulic fluids, greases and aerosol products

Relevant machine based standards:

Original equipment manufacturers use the standards published by the International Standards Organization (ISO) with appropriate regional and local legislative alterations.

AS 2106.2 – 2005 *Methods for the determination of the flash point of flammable liquids (closed cup) Part 2: Determination of flash point – Pensky-Martens closed cup method.*

AS 2585 – *2006 Determination of flash and fire points – Cleveland open cup method*

AS 3997.1 – 1992 *Fluid power – Fire-resistant hydraulic fluids Part 1: Classification*

AS 3997.2 – 1993 *Fluid power – Fire-resistant hydraulic fluids Part 2: Guidance on the selection, use and storage – commercial product*

ISO 12922 CEN/TR 14489 now ISO.TS 15029-2: 2012: *Petroleum and related products -- Determination of spray ignition characteristics of fire-resistant fluids -- Part 2: Spray test -- Stabilized flame heat release method* (withdrawn) specifies a method by which the fire hazards of pressurised sprays of fire-resistant fluids can be compared.

ISO/AWI 13649: *Earth Moving Machinery – Fire Prevention*. Under development – draft standard for fire prevention on earth moving machinery.

ISO 14935: *Petroleum and related products – Determination of wick flame persistence of fire-resistant fluids* – specifies a method for assisting the persistence of a flame applied to the edge of a wick of non-flammable material immersed in fire-resistant fluid.

ISO 15029: *Petroleum and related products – Determination of spray ignition characteristics of fire-resistant fluids* consists of three parts: part 1: spray flame persistence – hollow-cone nozzle method; part 2: spray test – stabilized flame heat release method; part 3 spray test – large scale method.

ISO/FDIS 19296: *Mining – Mobile machines working underground – Machine safety*. Under development (due to be published in 2018) final draft international standard for underground mobile mining machinery

ISO 20474-1:2008: *Earth moving machinery – Safety – Part 1: General Requirements*. Specifies the general safety requirements for earth-moving machinery.

ISO 20823:2003: *Petroleum and related products – determination of the flammability characteristics of fluids in contact with hot surfaces – manifold ignition test* specifies a test method to determine the relative flammability of fluids when contacted with a hot metal surface at a fixed temperature.

ISO 4413:2010: *Hydraulic fluid power – general rules and safety requirements for systems and their components* specifies general rules and safety requirements for hydraulic fluid power systems and components used on machinery as defined by ISO 12100.

ISO 6743-4:2015: *Lubricants, industrial oils and related products* (class L) establishes detailed classification of fluids of family H (Hydraulic systems) which belong to class L (lubricants, industrial oils and related products)

ISO 7745:2010 *Hydraulic fluid power— Fire-resistant (FR) fluids — Requirements and guidelines for use* specifies the operational characteristics for the various categories of fire-resistant fluids, details the factors to be considered when selecting a fluid from these categories for a proposed application and identifies difficulties which might arise from the use of such fluids and indicates how they may be minimized. Appropriate procedures are given for replacing one fluid with another from a different category. Health and safety aspects when handling and disposing of fire-resistant fluids are also covered.

ISO/IEC 80079.36:*2016: Explosive atmospheres – Part 36: Non-electrical equipment for explosive atmospheres – basic method and requirements* specifies the basic method and requirements for design, construction, testing and marketing of non-electrical Ex equipment, Ex components, protective systems, devices and assemblies of these products that have their own potential ignition sources and are intended for use in explosive atmospheres.

ISO/IEC 80079.37:2016: *Explosive atmospheres – Part 37: Non-electrical equipment for explosive atmospheres – Non-electrical type of protection constructional safety "c", control of ignition sources "b", liquid immersion "k"* specifies the requirements for the design and construction of non-electrical equipment intended for use in explosive atmospheres, protected by the types of protection constructional safety "c", control of ignition source "b" and liquid immersion "k".

ISO/IEC 80079.38:2016 *Explosive atmospheres – Part 3838: Equipment and components in explosive atmospheres in underground mines* specifies the explosion protection requirements for the design, construction, assessment and information for use of equipment for use in mines that is susceptible to explosive atmospheres of firedamp and/or combustible dust. It also deals with the prevention of ignitions of explosive atmospheres caused by burning (or smouldering) of combustible material such as fabric fibres, plastic "O"-rings, rubber seals, lubricating oils or greases used in the construction of the equipment if such items could be an ignition source.

HSE RR980 – *Generation of flammable mists from high flashpoint fluids*: guidance for high flashpoint liquid releases that could give rise to an explosive mist atmosphere.

HSE L11.6/3 *HSE Approved specifications for fire-resistance and hygiene of hydraulic fluids for use in machinery and equipment in mines* provides requirements for fire-resistant fluids intended for use in underground mines and gives guidance on minimum level of safety in application.

Key Sources

Issues identified in this paper have been drawn from the following sources:

NSW Resources Regulator; *In-service fires on mobile plant* 2017; available at: https://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0008/738341/In-service-fires-on-mobile-plant.pdf

NSW Resources Regulator; *Mining Design Guideline MDG 1032 Guideline for the prevention, early detection and suppression of fires in coal mines*; 2009; available at: https://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0017/420146/MDG-1032.pdf

NSW Resources Regulator; *Mining Design Guideline MDG 15; Mobile and transportable plant for use on mines and petroleum sites*; 2018; available at: https://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0003/796602/MDG-15-Guideline-for-mobile-and-transportable-plant-for-use-at-mines-other-than-underground-coal-mines.pdf

Mobil; Technical Topic — Fire-Resistant Fluids — Conversion and Compatibility; available at: https://www.mobil.com/.../tt-conversion-and-compatibility-of-fire-resistant-fluids.pdf

Generation of flammable mists from high flashpoint fluids: Literature review; Health and Safety Laboratory, Health and Safety Executive (UK) http://www.hse.gov.uk/research/rrpdf/rr980.pdf